

2016 DOE Vehicle Technologies Program Review Presentation

Energy Impact of Connected and Automated Vehicles
Project ID #VS173

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Overview

Timeline

- Start date: 2015/10/01
- End date: 2018/12/31
- Percent complete: 10%

Budget

- Total project funding
 - DOE share: \$2,673,096
 - Contractor share: \$297,101
- Funding received in FY15: \$0
Funding for FY16: \$1,082,074

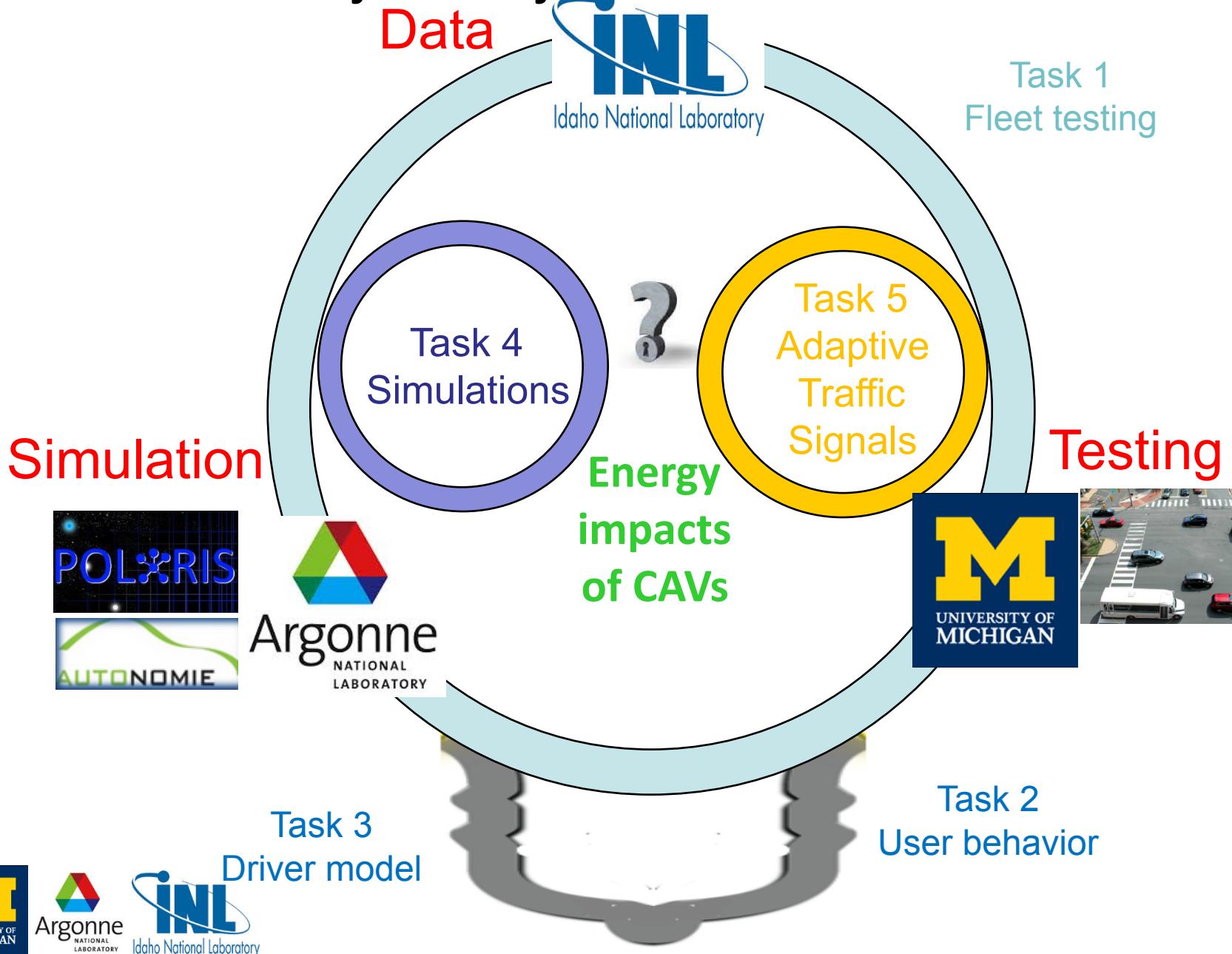
Barriers

- Data system definition
- Volunteer driver recruiting
- Develop models and test fleet that support a system solution that does not yet exist

Partners

- University of Michigan (AA)
- Argonne National Lab
- Idaho National Lab

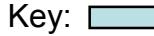
Project Objective-Relevance



Objectives / Relevance

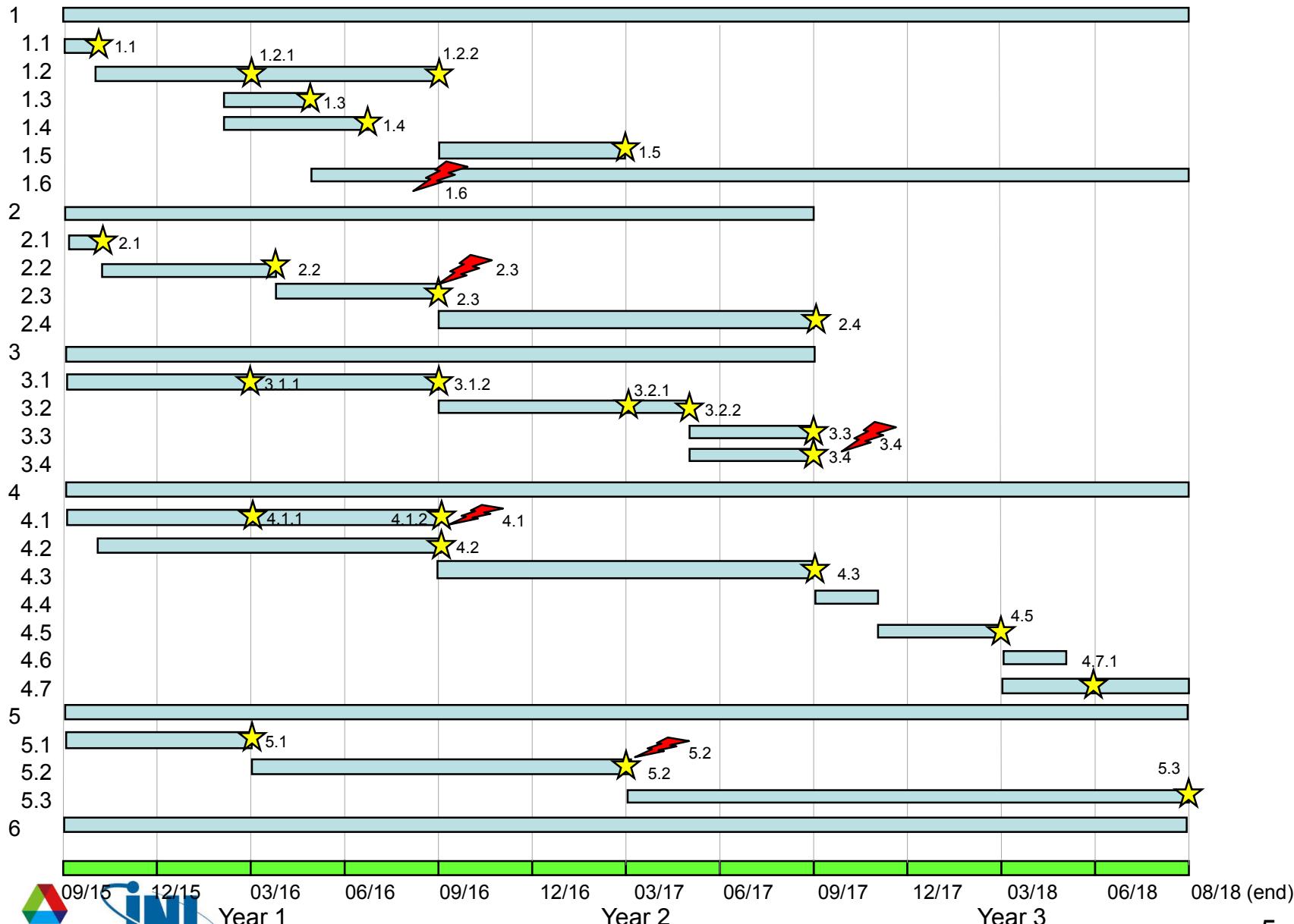
- Deploy logging devices in order to assess energy usage on a large naturalistic fleet of passenger vehicles.
- Test data used to develop model that can simulate the impact of energy consumption at a large scale (e.g., city of Ann Arbor). The model will include consider human behaviors

Project Timeline- Milestones and Go/No-Go

Key:  Task

 Milestone

 Go/no-go point



FY2016 Milestones and Go/No-Go

Task No.	Task Title	Milestone Type	Milestone Number	Milestone Description (Go/No-Go Decision Criteria)	Milestone Verification	Anticipated Date	Anticipated Quarter
1.1	Coordinate and prioritize signals	Milestone	1.1	Defined “data needs” based on POLARIS and Autonomie models and CAV functions	UM/ANL/INL	M1	1
1.2	Main data acquisition/storage/transmission hardware development	Milestone	1.2.1	Data needs defined which can be used to guide hardware selection	UM/ANL/INL	M6	2
1.2	Main data acquisition/storage/transmission hardware development	Milestone	1.2.2	500 vehicle fleet instrumented and data start to be collected	UM	M12	4
2.2	Develop driver information display hardware and communication	Milestone	2.2	Driver information display hardware and communication designed and document produced	UM/ANL	M7	3
2.3	Design vehicle information display screen(s) and experimental cases	Milestone	2.3	The overall energy display system is fully defined and designed	UM/ANL	M12	4
2	Display energy related information to study its influence on the driver	Go/no-go decision	2	Review of Task2 system design and quality	UM/ANL	M12	4
3.1	Modeling en-route driving behavior with SPaT information	Milestone	3.1.1	Development of basic structure of the tactical driver behavior models	UM/ANL	M6	2
3.1	Modeling en-route driving behavior with SpaT information	Milestone	3.1.2	Finalized driver behavior models	UM/ANL	M12	4
4.1	Implement baseline POLARIS model	Milestone	4.1.1	Determination of study area and development of baseline model	UM/ANL	M6	2
4.1	Implement baseline POLARIS model	Milestone	4.1.2	Assessment of behavioral implications of selected CAV technologies	UM/ANL	M12	4
4.2	Determine quantity and quality of data needed for model	Milestone	4.2	Data needs assessment for POLARIS model	UM/ANL	M10	4
5.1	Build and calibrate the traffic simulation environment	Milestone	5.1	Developed simulation model	UM/ANL	M6	2

Approach/Strategy

- Five coordinated tasks among three leading CAV research organizations
- Leverage the connected vehicle fleet already deployed at [UofM](#), add “energy focus”.
- Leverage [INL](#)’s expertise in monitoring and analyzing advanced technology vehicle performance and driving conditions to determine how driver behavior and usage conditions affect energy consumption of the vehicles.
- Leverage [ANL](#)’s expertise in modeling (Polaris and Autonomie)
- Final outcome: tools and test platforms that can be used to evaluate the energy impact of CAVs

Technical Accomplishments—Task 1

- Task: COTS loggers using the OBD-II port and custom configurations to collect CAN bus data.
 - Established data requirements and state-of-art of collection devices and backends.
 - Logger vendor RFQ being released.
- Task: Fuse onboard data with AACVTE data and later with intersection monitoring data to provide a basis for assessing CAV impacts on energy.
 - Logger RFQ includes requirements that will allow fusing vehicle, roadside, and existing data sets. UMTRI experienced in this task.

Technical Accomplishments—Task 1

- Challenge: Recruiting enough drivers
 - Will co-recruit drivers with UMTRI's US DOT project, "Ann Arbor Connected Vehicle Test Environment (AACVTE)." AACVTE provides DSRC device and this project installs OBD-II logger.
 - Logger vendor RFQ being released.



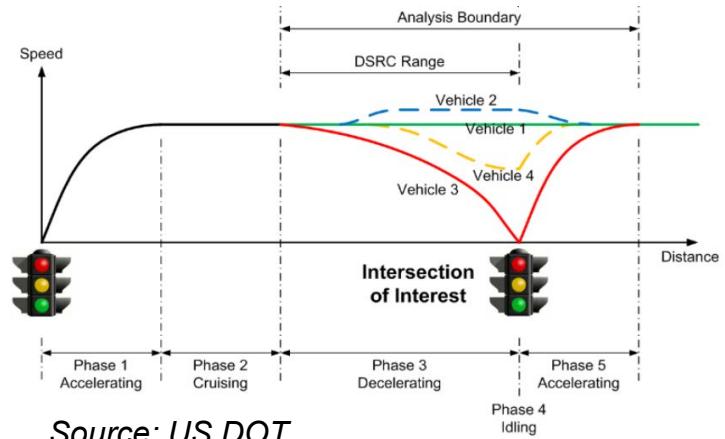
Figure 1: The Danlaw Datalogger



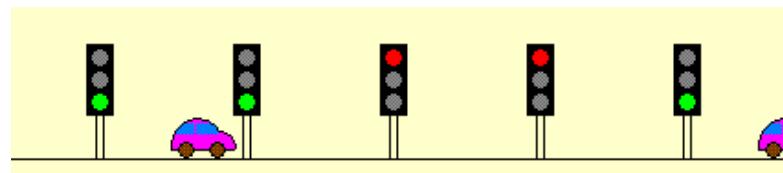
Figure 2: Typical locations of the OBDII port in most light vehicles

Technical Accomplishments—Task 2

- Task: Identify CAV user functions, co-design and prioritize signals
- Two key CAV functions were identified that both show significant potential, and had not been implemented in large-scale experiments
 - Eco-Approach and Departure
 - Uses SPaT information
 - Advisory speed to drivers
 - Green wave (suggested speed)
 - Uses mostly the same SPaT info, just presented differently to the driver for longer ranges



Source: US DOT



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Technical Accomplishments—Task 2

- Challenge: How to design an HMI that is truly useful to the drivers in the real-world scenarios
 - Assumption 1: Not all information are equally effective
 - Advisory speed, SPaT countdown info, distance to intersection, advisory actions (e.g., “slightly speed up”), etc.
 - What information should be included and how they should be presented?
 - Assumption 2: Drivers may not need the information at all time and in all circumstances
 - A driver on a straight road may be able to roughly guess the next light change if he/she saw the previous light change
 - The vehicle is blocked by the traffic
 - Whether or not, and when the display should be presented?
 - How to meet this challenge
 - Case studies of typical scenarios using existing CAV data
 - Focus group
 - User-centered, iterative design

Technical Accomplishments—Task 3

- **Goal:** To model how CVs/AVs change driving/travel behavior and explore their implications for energy consumption
- **Technical approach:**
 - Experiment: to study how energy inspired information will change driving and travel behavior
 - Modeling: to model the AV impact, we will employ the distributed optimization approach
- **Uniqueness**
 - The first field experiment validating the impact of CV on driving/travel behavior
 - The first large-scale optimization model of household travel activity patterns with AVs

Technical Accomplishments—Task 3

- **Progress:**

- Prepare for the survey and field experiment: designing survey questions, detailing an implementation plan including data needed for this task (behind schedule due to coordination with Task 1/2 and IRB)
- Working on analytical modeling: conducting a comprehensive literature review (on schedule)



9:30

departure-time choice

pre-trip/en-route choice



activities scheduling/sequences

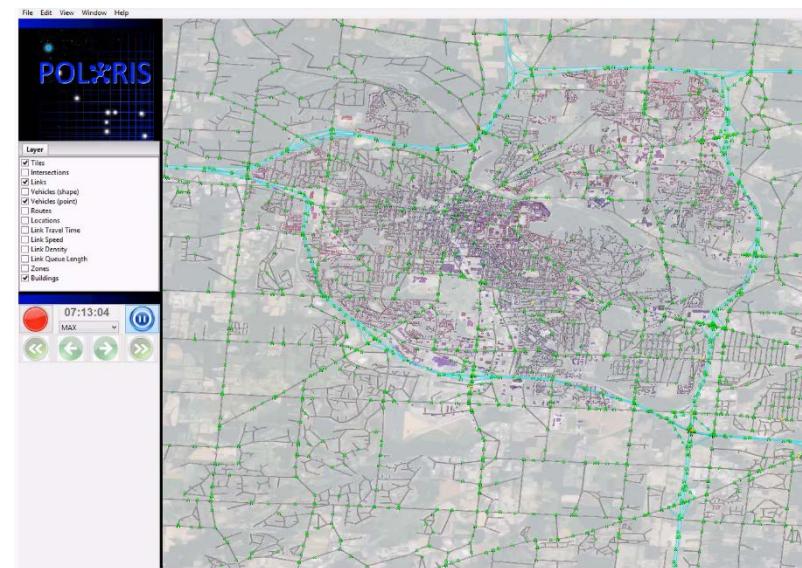
Technical Accomplishments—Task 4

- Task objectives:

- Develop regional travel demand/energy use simulation model for Ann Arbor, incorporating information from UM test fleet
- Understand potential impact on behavior of various CAV technologies (connected intersections, eco-routing, CACC) in a simulation environment before deployment
- Evaluate energy impact through simulation and compare to real world data from loggers

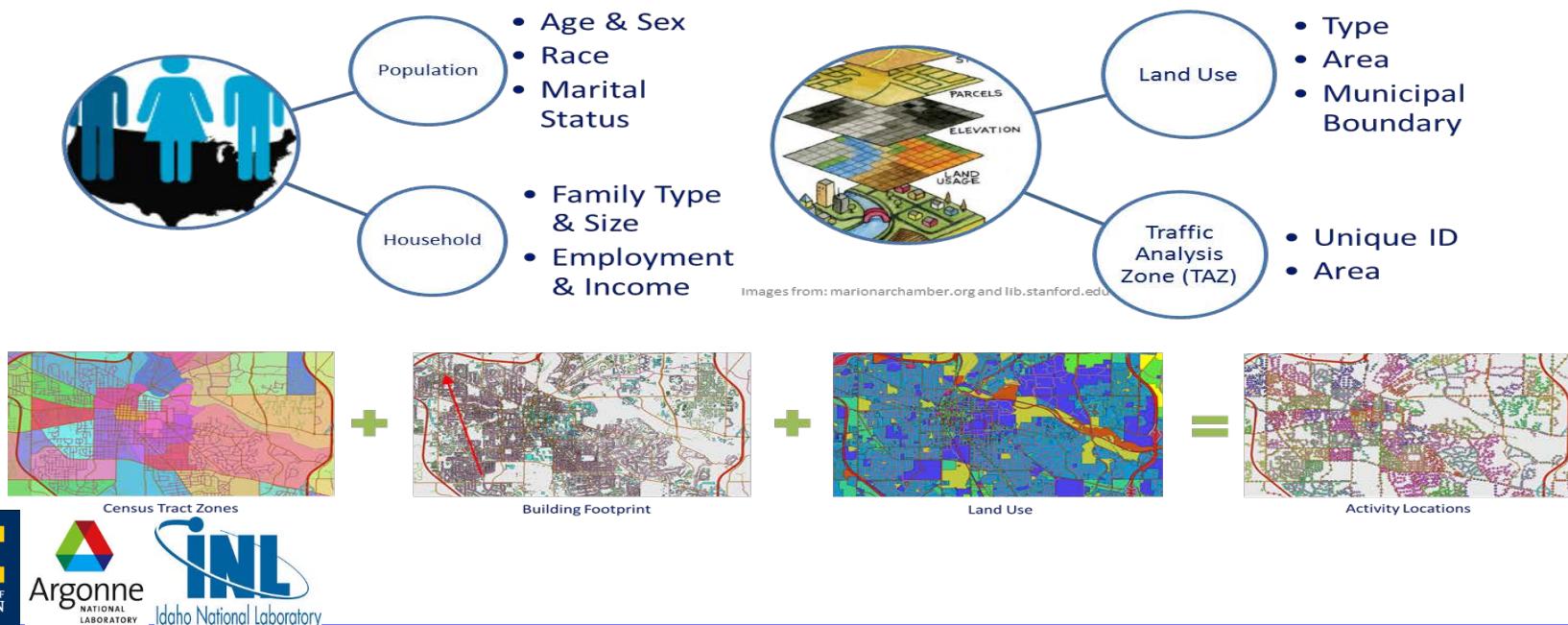
- Technical approach / strategy

- Develop algorithms/software for converting GPS traces into individual travel and network performance data
- Incorporate new behavior models of CAV response based on surveys/data collection
- Calibrate POLARIS model using fleet data
- Verify energy consumption models using energy consumption from loggers
- Simulate regional energy consumption for various CAV scenarios



Technical Accomplishments—Task 4

- Ann Arbor baseline model implemented
 - Critical issue: base and forecast year employment data is unavailable – need to develop models for employment for forecast years, and work with alternate sources for base year (LEHD, economic census, land use, etc.)
- Development of high performance GPS trace analysis software
 - Currently updating to National Cooperative Highway Research Program Guidelines (report NCHRP-8-89) for trip reconstruction from GPS
 - Critical issue: availability of non-anonymized data, and to handle large scale of data. Address this issue by running locally on UM server



Technical Accomplishments—Task 5

- Objectives

- Design adaptive signal control models in a CAV environment with the focus on energy saving
 - Implement the models in both hardware-in-the-loop simulation environment and real world testbed

- Technical Approach

- Modeling: We will utilize CAV trajectory data to formulate the adaptive signal control to an optimization problem with the objective to minimize fuel consumption/emission.
 - Data collection: We will design a data hub device to collect real-time CAV data.
 - Implementation: M-City and a six-intersection corridor at Plymouth Rd, Ann Arbor, will be used for field tests.

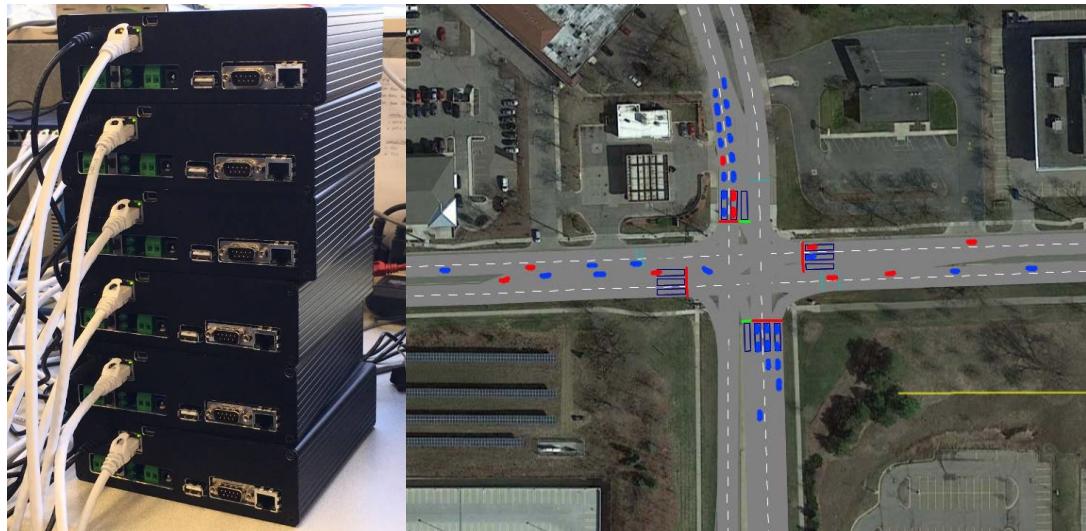
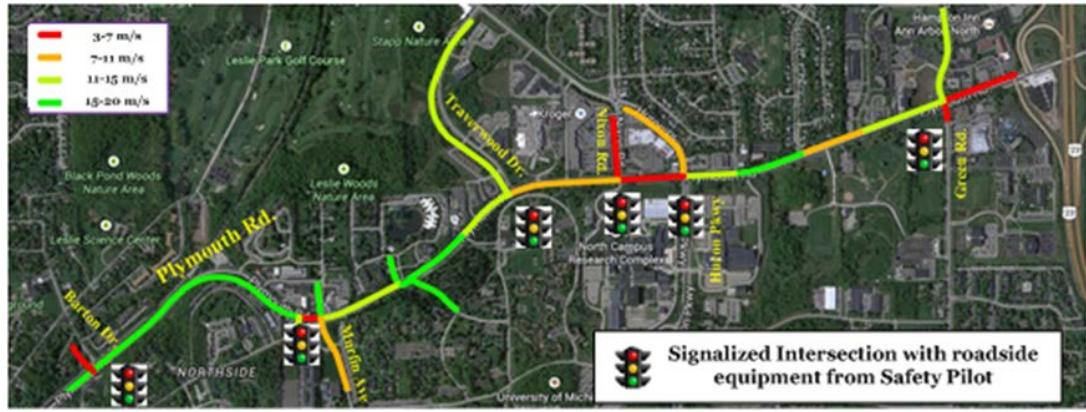
- Uniqueness

- The first field implemented adaptive signal control system with a large amount of CAV from the safety pilot project fleet
 - The first data hub device which is able to collect different types of real-time data at an intersection (CAV data, signal data and loop-detector data).

Technical Accomplishments—Task 5

- Progress

- A microscopic simulation model of 6 intersections at Plymouth Rd is constructed and calibrated
- Generate surrogate basic safety messages (BSM) from the simulation based on SAE J2735 standards
- Design and build the data hub device



Responses to Previous Year Reviewers' Comments

- N/A (projected started Oct 2015)

Collaboration and Coordination with Other Institutions

- Prime: University of Michigan (University)
- Sub: Argonne National Lab and Idaho National Lab (national labs)
- Other collaborators:
 - UM UMTRI/MTC (leverage their connected vehicle fleet)
 - Danlaw and Cohda: suppliers of data logger and DSRC system
 - EPA: Consultation for signals to collect, key model outputs and key CAV functions

Challenges and Barriers

- Design of the data logging system that collect data useful for Polaris/Autonomie models
- Recruiting of volunteer drivers
- Mutual dependency of the progress in test design and model development. For example, which connected function to implement first, can benefit from simulation results. But the model is not yet verified.

Proposed Future Work

- Volunteer driver recruiting
- Design of a thoughtful human interface and experiment plan
- Concept design of a large-scale modeling of household travel activity optimization
- Analyze and incorporate travel demand from SE Michigan in the Ann Arbor model
- Assessment of behavioral implications of select CAV technologies leading into the data needs assessment for POLARIS
- Use software to convert connected vehicle safety pilot data into synthetic travel survey for model estimation/calibration of baseline POLARIS model
- Estimation and calibration of base and CAV behavioral models

Proposed Future Work—cont.

- Develop adaptive signal control models and algorithms to reduce energy use and congestion
- Acquire 500 data logger and integrated into the existing UM connected vehicle fleet.

Summary

- Project started a little late due to student recruiting
- Overall project progress is catching up
- Data logger will be selected and installed this summer
- Two UM students will go to ANL in summer to accelerate implementation of CAV functions in Polaris
- Polaris is being converted to more accurately simulate the effect of CAV functions on energy consumption
- The team has met EPA researchers twice to gather their input and suggestion for this project